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APOLLO MISSION F
REFERENCE CONSUMABLES ANALYSIS

68-FM-267



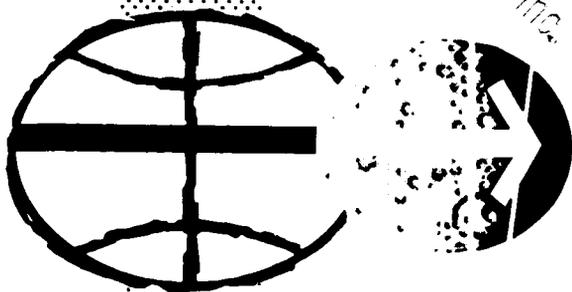
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PROJECT APOLLO
APOLLO MISSION F
REFERENCE CONSUMABLES ANALYSIS

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FOREWORD

The following table summarizes the consumables requirements for Mission F.

Consumable	Percentage of available used for mission planning
CM RCS	12.6
SM RCS	64.7
SPS	^a 90.5
LM RCS	67.0
DPS	5.3
APS	^a 5.5
CSM O ₂	77.3
CSM H ₂	78.4
LM descent battery	36
LM ascent battery	81
LM descent O ₂	6.8
LM ascent O ₂	36.6
LM descent H ₂ O	22.2
LM ascent H ₂ O	84.6

^aAnalysis based on 100 percent APS loading

These results were obtained from consumables analyses performed on the Mission F RCS, SPS, APS, DPS, EPS, and ECS. The data used in the RCS, EPS, and ECS analyses were assumed accurate to within ± 10 percent.

All analyses were performed prior to the publication of the flight plan and reference trajectory, which is the reason this document is abbreviated. As the flight plan is specified, the analyses will be expanded and the results published as updates to this document.

SYMBOLS

AGS	abort guidance subsystem
APS	ascent propulsion subsystem
CDH	constant differential height
CDR	commander
c.g.	center of gravity
CM	command module
CO ₂	carbon dioxide
CSI	coelliptical sequence initiation
CSM	command and service module
DOF	degrees of freedom
DOI	descent orbit insertion
DPS	descent propulsion subsystem
ECS	environmental control subsystem
EPS	electrical power subsystem
GNCS	guidance and navigation control subsystem
H ₂	hydrogen
I _{fc}	fuel cell current
IMU	inertial measurement unit
LiOH	lithium hydroxide
LM	lunar module
LMP	LM pilot
LOI	lunar orbit insertion

MCC	midcourse correction
MPD	main powered descent
MTVC	manual thrust vector control
O ₂	oxygen
PGNCS	primary guidance and navigation control subsystem
PU	propellant utilization
RCS	reaction control subsystem
RSS	root-sum-square
SLA	spacecraft LM adapter
SM	service module
SPS	service propulsion subsystem
T	lift-off
T&D	transposition and docking
TEI	transearth injection
TLMC	translunar midcourse
TEMC	transearth midcourse
TPF	terminal phase finalization
TPI	terminal phase initiation

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1.0 THE CM RCS ANALYSIS

TABLE 1-I.- CM RCS PROPELLANT SUMMARY

Description	RCS propellant used, lb	RCS propellant remaining, lb
Loaded		270.0
Trapped	32.4	237.6
Temperature variation	6.4	231.2
Available for mission planning		231.2
Nominal usage ^a	29.4	201.8
Operational reserve		201.8

^aFrom reference 1.

2.0 THE SM RCS ANALYSIS

TABLE 2-I.- SM RCS PROPELLANT SUMMARY

Description	Propellant load, lb	Propellant remaining, lb
Maximum loaded		1362
Unusable		
Loading and temperature dispersions	31	1331
Trapped and unexpelled	27	1304
Mixture ratio and gauging allowance	82	1222
Available for mission planning		1222
Nominal usage		
Translunar phase	185	1037
Lunar orbit phase	509	528
Transearth phase	97	431
Operational reserve		431

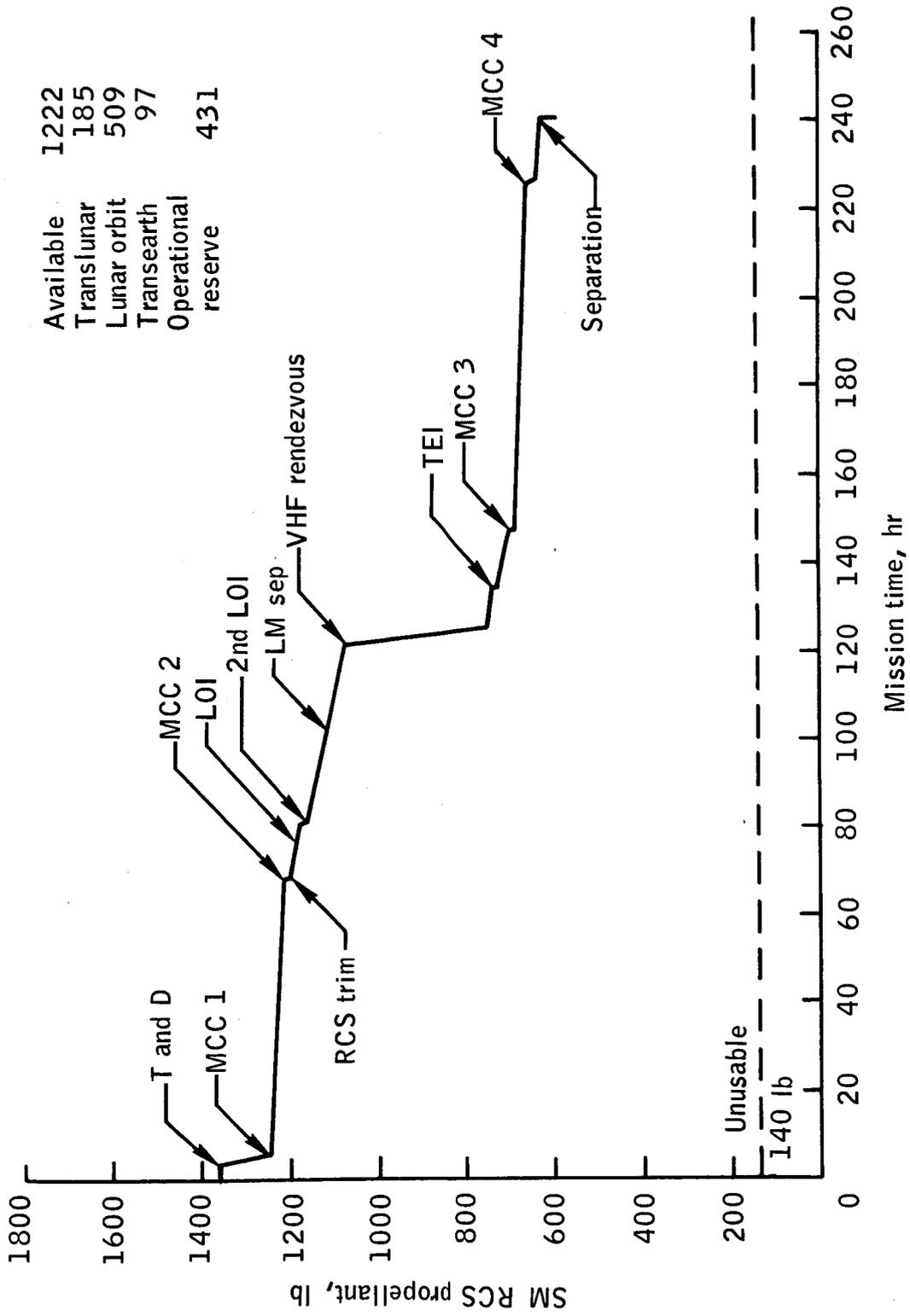


Figure 2-1. - SM RCS propellant as a function of time.

3.0 THE SPS ANALYSIS

TABLE 3-I.- ASSUMPTIONS MADE IN THE SPS CONSUMABLES ANALYSIS

1. Loaded propellant - This is the sum of 39 754 lb of tanked propellant (ref. 2, Mission F) and 202 lb of propellant trapped outside the tanks (ref. 2, Mission G).
2. Trapped propellant - This propellant is physically unavailable for use and includes propellant trapped as vapor and in the retention reservoir.
3. Mixture ratio uncertainty - There can be a propellant cost of 245 lb due to a mixture ratio uncertainty within the limits of the unbalance meter and PU value operation. This includes propellant cost due to meter uncertainty and gauging system accuracy.
4. Start losses - There is a nonpropulsive propellant loss of approximately 14.4 lb for each burn.
5. Propellant available for ΔV - This number does not account for propellant loading uncertainties. Loading uncertainties are included in the dispersions. (See item 7 below and table 3-II.)
6. Propellant required for ΔV - Trajectory ΔV requirements are best current estimates.
7. Dispersions - There is a preliminary estimated dispersion of 300 lb due to loading uncertainty, performance dispersion, and GNCS dispersions.
8. LM rescue propellant - This is the propellant cost for a worst case LM rescue of 650 fps. Actual propellant usage for LM rescue is 2315 lb. However, there would be a propellant saving of 496 lb for TEI due to the lighter spacecraft and of 385 lb due to cancellation of the nominal rendezvous. Hence, total propellant cost for LM rescue is 1434 lb.

TABLE 3-II.- SPS PROPELLANT SUMMARY

Description	Propellant used, lb	Propellant remaining, lb
Loaded		39 956.0
Trapped and unavailable ^a	441.4	39 514.6
Mixture ratio uncertainty	245.0	39 269.6
Start losses (8 starts)	115.2	39 154.4
Available for ΔV		39 154.4
Required for ΔV		
TLMC (120 fps)	1 132.7	38 021.7
LOI (2975.9 fps)	24 156.9	13 864.8
Circularization (139 fps)	963.9	12 900.9
NCC (71.2 fps)	256.0	12 644.9
NSR (36.1 fps)	129.1	12 515.8
TEI (2713.2 fps)	8 617.4	3 898.4
TEMC (62 fps)	170.8	3 727.6
Dispersion	300.0	3 427.6
LM rescue	1 434.0	1 993.6
Operational reserve		1 993.6

^aReference 2, Mission G.

4.0 THE LM RCS ANALYSIS

TABLE 4-I.- THE LM RCS PROPELLANT SUMMARY

Description	Propellant used, lb	Propellant remaining, lb
Loaded ^a		638
Unusable		
Loading and temperature dispersions Trapped and unexpelled	10 40	628 588
Minimum deliverable		588
Unusable, for mission planning		
Mixture ratio uncertainty	17	571
Gauging accuracy	64	507
Available for mission planning		507
Mission requirements		
Usage through APS insertion burn	68	439
Rendezvous through docking	263	176
Attitude hold for CSM active flyby	8	168
Operational reserve		168

^aMaximum loaded, where nominal loaded is 633 lb. Unusables are consistent with maximum loading for purposes of calculating minimum deliverables.

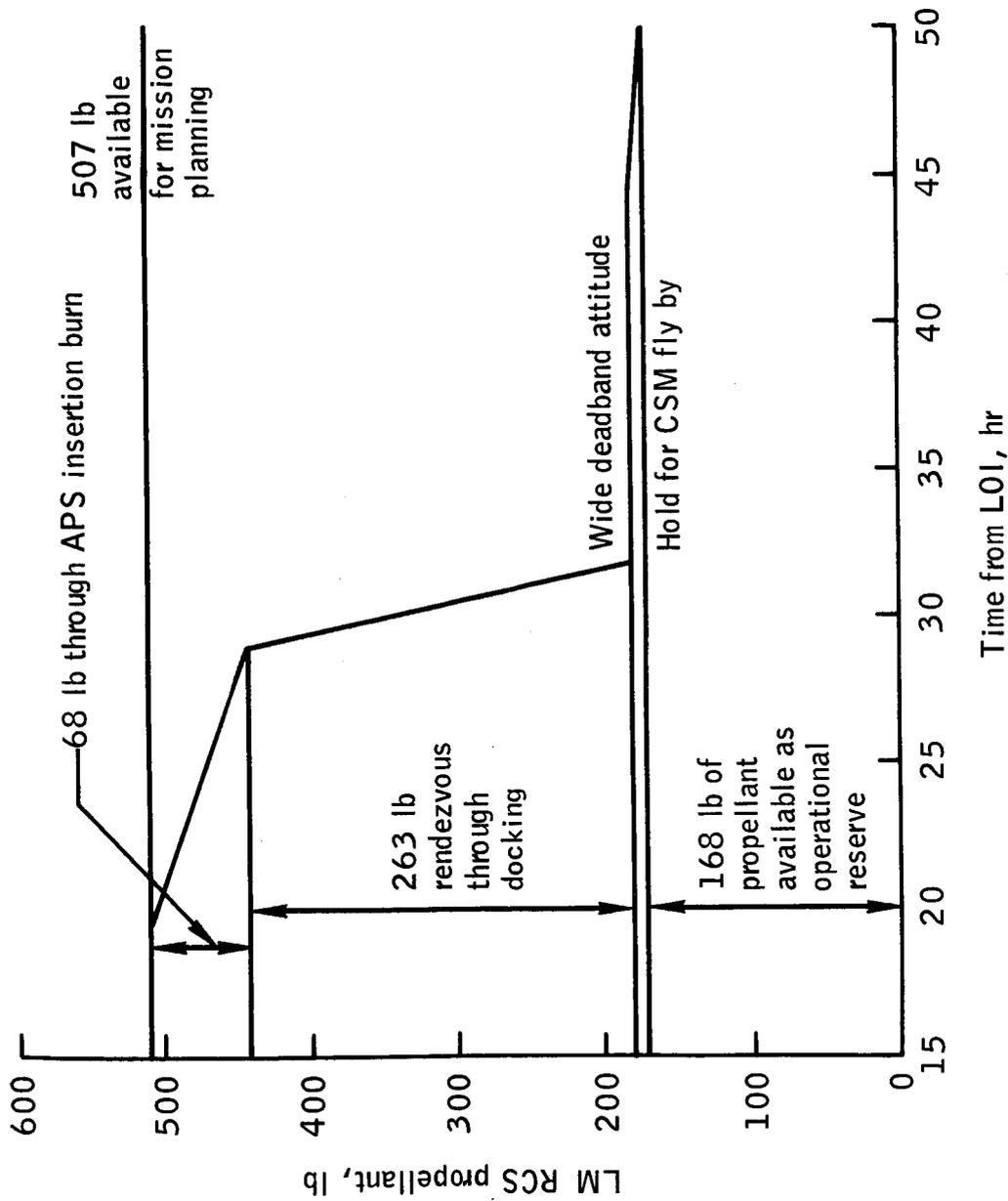


Figure 4-1.- LM RCS propellant as a function of time from LOI.

5.0 THE DPS ANALYSIS

TABLE 5-I.- ASSUMPTIONS FOR THE DPS ANALYSIS

1. Usable propellant - This was obtained from reference 2.
2. Propellant required for ΔV - This is based on the assumptions of a 10 percent thrust level (worst case) and a specific impulse of 289 seconds.
3. Due to the large propellant quantity remaining and the lack of knowledge of data for this mission, there is no propellant allowance made for performance dispersions or mission contingencies.

TABLE 5-II.- DPS PROPELLANT SUMMARY

Description	Propellant used, lb	Propellant remaining, lb
Usable propellant		17 510
Required for ΔV		
DOI (70.9 fps)	252	17 258
Phasing burn (190.5 fps)	668	16 590
Nominal remaining		16 590

6.0 THE APS ANALYSIS

TABLE 6-I.- ASSUMPTIONS FOR THE APS ANALYSIS

1. Usable propellant - This was obtained from reference 2.
2. Required for ΔV - Burns using the APS engine assumed a specific impulse of 306.3 seconds (ref. 3).
3. As with the DPS, there is a large amount of propellant remaining and very little knowledge of mission data at this time. Hence there is no propellant allowance made in this analysis for performance dispersions or mission contingencies.

TABLE 6-II.- APS PROPELLANT SUMMARY

Description	Propellant used, lb	Propellant remaining, lb
Usable propellant		5044
Required for ΔV		4791
Insertion (229.7 fps)	253	
CSI (47.6 fps using RCS interconnect)	23	4768
Nominal remaining		4768

7.0 THE CSM EPS ANALYSIS

TABLE 7-I.- ASSUMPTIONS FOR THE EPS ANALYSIS

1. EPS hydrogen consumption rate = $.00257 \times I_{FC}$ (lb/hr).
2. EPS oxygen consumption rate = $7.936 \times$ hydrogen consumption rate (lb/hr).
3. The system was assumed to operate with two inverters.
4. Component power requirements were taken from reference 3.
5. Entry and postlanding batteries - Three batteries were considered in supplying the total spacecraft power requirement for entry, parachute descent, stabilization period at impact, and postlanding. A battery capacity of 40 A-h per battery was assumed with 120 A-h available prior to CM/SM separation.
6. No venting of cryogenic oxygen or hydrogen was assumed.
7. The phase duration used was

Earth parking orbit, hr	1.97
Translunar coast, hr	74.60
Lunar orbit, hr	50.00
Transearth coast, hr	89.50
Total time, hr	<u>216.07</u>

TABLE 7-II.- CSM CRYOGENICS SUMMARY

Item	H ₂ , lb	O ₂ , lb
Total loaded	58.4	653.0
Unusable	2.4	13.0
Gauging Error (2.65 percent)	1.5	17.0
Total usable for mission planning	54.5	623.0
Uncertainty in EPS profile	3.6	28.5
Nominal mission prelaunch requirements	3.2	31.6
Flight (power and purge)	35.9	285.2
ECS requirements		136.2
Margin	11.8	141.5

TABLE 7-III.- CM BATTERY REQUIREMENTS FOR
ENTRY AND POSTLANDING

Item	Requirement, A-h
Available battery	120.0
Used for CM/SM separation to entry	15.0
Parachute descent	5.8
Used for two uprightings	8.4
Used for 48 hours postlanding	63.4
Total required	92.6
Remaining	27.4

TABLE 7-IV.- PRELAUNCH CSM FUEL CELL

REQUIREMENTS AND PROCEDURES

Time	Fuel cell current, A	H ₂ , required, lb	O ₂ , required, lb
(a) Requirements			
T - 22 hr to T - 3 hr	45	--	17.5
T - 16.5 hr to T - 3 hr	45	1.6	--
T - 3 hr to T - 2 hr	45	.1	1.2
T - 2 hr to T - 0 hr	90	.5	4.1
4.25 hr launch window	90	1.0	8.8
Total		3.2	31.6
(b) Procedures			
Time	Event		
T - 22 hr	Complete loading O ₂ , and switch to internal O ₂ for fuel cell requirements		
T - 16.5 hr	Complete loading H ₂ , and switch to internal H ₂ for fuel cell requirements		

8.0 THE CSM ECS ANALYSIS

TABLE 8-I.- ASSUMPTIONS USED FOR THE ECS ANALYSIS

1. Metabolic O_2 rate was 0.0766 lb/hr for each man.
2. Waste management O_2 rate was 0.051 lb/hr for three men.
3. Cabin leak rate was 0.2 lb/hr. (Leak rate of the O_2 during the docked configuration with the hatch open was .5 lb/hr.)
4. O_2 purge rate of the water tank was 0.056 lb/hr.
5. A total of 4.5 lb of O_2 was purged through the waste management system during the first 5 hours of the mission to create a near oxygen atmosphere in the cabin.
6. Three pressurizations of the LM were assumed (only one was a full pressurization of 7.1 lb.)

TABLE 8-II.- CSM ECS OXYGEN REQUIREMENTS

Item	O_2 required, lb
Metabolic	47.8
Waste management	10.6
Cabin leakage	47.8
Water tank purge	12.1
Pressurization	18.9
Total	<u>136.2</u>

9.0 THE LM EPS ANALYSIS

TABLE 9-I.- LM EPS ASSUMPTIONS

1. Descent battery capacity was 400 A-h per battery and ascent battery capability was 296 A-h per battery.
2. The ascent stage utilized for this mission did not have the capability of accepting electrical energy from the CSM.
3. The ascent batteries were considered to be paralleled with the descent batteries 15 minutes prior to staging.
4. No PGNCs were considered operative during the CSM active rendezvous.

TABLE 9-II.- LM EPS SUMMARY

	Descent, A-h	Ascent, A-h
Total battery capacity	1600	592
Unusable	56	44
Required for Mission	560	444
Total usable remaining	<u>984</u>	<u>104</u>

10.0 THE LM ECS ANALYSIS

TABLE 10-I.- LM ECS ASSUMPTIONS

(a) Assumptions for O ₂ consumption
1. Cabin O ₂ leak rate 0.2 lb/hr.
2. Metabolic O ₂ consumed was (1.643×10^{-4}) total metabolic rate.
3. There were no pressurizations.
(b) Assumptions for the water balance analysis
1. Structural heat load was 1000 B.t.u./hr.
2 The LiOH-CO ₂ reaction requires (1.640×10^{-4}) (total metabolic rate) lb/hr of H ₂ O. (This includes the water produced minus the water used for cooling due to the heat generated.)
3. A water loss of 0.22 lb/hr due to micturation.

TABLE 10-II.- LM ECS SUMMARY

Description	O ₂ , lb	H ₂ O, lb
(a) Descent stage		
Usable	45.3	312.7
Required	3.1	69.3
Remaining	42.2	243.4
(b) Ascent stage		
Usable	4.1	80.4
Required	1.5	68.4
Remaining	2.6	12.4

REFERENCES

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